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RHIZOCTONIA SOLANI IN RELATION TO THE "MOPOPILZ" AND THE "VERMEHRUNGSPILZ"

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Discussing in a recent paper ('15) the distribution of *Rhizoctonia Solani* Kühn (*Corticium vagum* B. & C.) I made the following statements:

> "It is rather surprising to find that *R. Solani* has received relatively little attention in Europe. Although recognized as inducing a disease of the potato widely distributed in central Europe, and occasionally reported on the beet, yet little careful work has been bestowed upon the fungus."

I shall now endeavor to show, as definitely as a discussion of the literature will permit, that this statement requires material modification. At the same time the evidence indicates a considerable extension of the region in which this *Rhizoctonia* is important as a seed-bed parasite. The new light on the problem is a result of the provisional determination—amounting almost to a certainty—that the Javanese "Mopopilz" and the central European "Vermehrungspilz" are identical with *Rhizoctonia Solani* (*Corticium vagum* B. & C.).

Some years ago the writer attempted to determine the possible relation of *Rhizoctonia* to seed-bed or cutting-bench diseases in Germany, but at that time the literature was scant and confusing, so that the effort was unfortunately abandoned, largely, however, as a result of the suggestions from several sources, that *Pythium, Botrytis,* and other known forms were

clearly responsible for these diseases. It now appears that a considerable literature has been gradually accumulating, but it was not correlated with the work on *Rhizoctonia*, proceeding at the same time, owing largely to incorrect determinations. I owe the present outlook upon the literature to the illuminating paper of Rant ('15[a]) in which, it would seem, from his description and figures, that he clearly and correctly identifies the "mopo" fungus of Cinchona seed-beds in Java as *Moniliopsis Aderholdii*, described by Ruhland ('08) and designated by him as the cause of seed-bed and propagation-bed difficulties. It was necessary for me to go but a step further to determine that *Moniliopsis Aderholdii* is in reality identical with *Rhizoctonia Solani*. It seems well, however, to review briefly all the contributions thus far found which seem to shed light on this fungus as a cause of disease in propagating-beds, as studied in Europe and in Java, especially as it serves to supplement the literature cited in my recent paper (Duggar, '15).

Since comments will be made in connection with the review of literature, it may be well to emphasize certain characteristics particularly distinctive of *Rhizoctonia Solani*, and among those important are the following:

(1) The great variety of higher plants affected; (2) the rapidity of spread where seedlings are attacked, presenting an appearance as if hot water had been poured over the young plants; (3) the growth of a web of mycelium over the fallen plants and likewise over the adjacent soil, so that fragments of soil adhere when the plants are lifted;[1] (4) mycelium practically hyaline when young, with characteristic branching and septation, becoming brownish with age; (5) under favorable conditions, especially in culture, the development of floccose masses, consisting of chains of cells (Monilia-like), often much branched or elbowed, colorless to brownish; (6) the formation of dark brown sclerotial bodies, irregular in size and outline, developing in the same way as the floccose masses, but denser by anastomosis, with the form of the cells (in mature sclerotia) practically uniform throughout, that is, with no dif-

[1] This perhaps more than any other characteristic enables gardeners to distinguish the fungus from the effects of *Pythium* and of *Botrytis*.

ferentiated peripheral layer; and (7) cultures readily obtained from mycelium or sclerotium, the organism producing in culture only mycelium, flake-like masses or tufts, and effuse sclerotia.

In reviewing the earlier of these studies upon diseases of this type which may be caused by *Rhizoctonia* it is hazardous to attempt to interpret those cases in which the organism is inadequately described, yet bearing in mind the more striking characteristics of *Rhizoctonia,* it is believed that no literature is here included which does not suggest this fungus. In the later studies the organism has been for the most part so well described that little doubt may be entertained with respect to the determination. For the present it is necessary to rely upon a discussion of the literature, but when more material, in the form of cultures, from the regions here referred to is available, a supplementary statement will be required.

An examination of the files of the more important of the horticultural journals of both France and Germany prior to 1880, has been made with the result that references to diseases of cuttings and seedlings are found to be not infrequent, but without exception these contribute nothing, so far as I have been able to find, which will throw light upon the organism concerned. The earliest reference which has been found to be of importance is that of Therry and Thierry ('82). They reported having studied, for more than a year, the mycelial filaments which invaded the cutting-benches of gardeners and florists in the region of Lyons. Although unable to find a spore stage, they described the organism studied as *Mortierella arachnoides* Th. & Th. (araignée des serres), since they considered the vegetative stage to show a close relationship to *M. Ficariae* which they found on leaves of *Ficaria Ranunculoides. M. arachnoides* is described as killing the shoots and growing over the fallen tissues, disorganizing them with great rapidity, also growing over the soil in the form of a web of strands. The mycelium is said to be able to grow meters during a single night. The points noted, together with the brief description of the mycelium, strongly sug-

gest *Rhizoctonia,* and it would not be strange that sclerotia were absent under the conditions.

Prompted apparently by the account just referred to, and based somewhat upon that, von Thümen ('82) reports upon the "Vermehrungspilz," and this appears to be the first definite account of the organism from central Europe. His description of the mycelium adds somewhat to that of Therry and Thierry, and like them he found that "* * * die Untersuchungen nichts weiter ergab, als die Anwesenheit zahlreicher, spinnwebendünne, weisslicher oder bräunlicher Mycelfäden, von irgend einer Fructification aber trotz genauesten Suchens auch nicht die mindeste Spur aufzufinden war." Whatever may be the interpretation of these two sets of observations they emphasize (1) the rapidity of growth and violence of the attacks of the organism concerned and (2) the presence of a mycelium as the only stage of the associated organism.

It appears probable that the disease which came to be known as "maladie de la toile" in France is the same as that referred to by Therry and Thierry ('82); nevertheless, such observations as are reported during the next fifteen years leave the question of a causal organism in an unsatisfactory state. Mangin ('94) refers to "la toile" as the disease due to a fungus occurring both in the greenhouse and in the open, producing a decay of leaves and branches, especially at or near the surface of the soil. Recalling what has already been said regarding this fungus it is significant that he remarks: "Quand la *Toile* est bien développée, les filaments mycéliens agglutinent les fragments de terre et deviennent très visibles." Collecting material from the affected area he found that in a few days conidiophores of *Botrytis* appeared on the dead leaves. With cultures of the *Botrytis* he reproduced a disease in lettuce. Since, however, *Botrytis cinerea* might occur upon any debris, and since it also produces a disease of lettuce, it does not follow, of course, that it is the fungus responsible for the troubles here referred to. From the description of the effects, one is inclined to reject the idea that *Botrytis* is concerned in this case. In the same year Prillieux

and Delacroix ('94) found "la toile" abundant in the seed and propagating-beds, market gardens, etc., near Fontainebleau. Affected plants were infested with a sterile mycelium, and they found a fungus, identified as *Botrytis cinerea,* fruiting on the dead material, from which they prepared cultures. No infection experiments were made, and they report no attempt to ascertain if the mycelium in the tissues were really that of *Botrytis.* No additional information is advanced in Mangin's ('94[a]) second paper.

Sorauer ('96) refers to the "Vermehrungsschimmel" of the cutting-benches and of seed-beds as probably belonging to the genus *Sclerotinia.* Reference is made to the spider web-like mycelium, lack of sporophores, and the presence of sclerotia. It is apparently on account of the sclerotia that he refers the fungus to *Sclerotinia.* He indicates that this organism is the chief fungus of the cutting-bench, although *Mucor, Botrytis,* and other organisms may also be found. The description, though far from being complete, is applicable to *Rhizoctonia.*

Aderhold ('97) characterized the fungus and its effects in some detail, and there can be little doubt that he was dealing with the disease then recognized as widely distributed. Moreover, unlike those who preceded him, he obtained the sterile fungus in culture, observed the Monilia-like chains of cells, and also the formation of sclerotia. It seems remarkable that it did not suggest to him Kühn's potato fungus. On the contrary, he agreed with Sorauer in referring the fungus to *Sclerotinia,* without indicating the species.

In a second paper Sorauer ('99) also discusses the fungus more completely. He refers to much of the earlier work, including that of Aderhold. Various stages of the fungus are figured, that is, the mycelium, the moniliform hyphal cells, and the sclerotia, all stages pointing to *Rhizoctonia.* He also refers to a characteristic of his fungus, since frequently observed, doubtless, by all who have studied *Rhizoctonia* in liquid cultures, namely, that of growing up the walls of the vessel above the level of the liquid. He also examined the affected tissues and was able to follow the mycelium in its advance, showing its penetration into the inner bark, like-

wise into the mesophyll of affected leaves. Comment is made on the fact that the death of the cells ensues when very few hyphae have penetrated the tissues.

A review of the earlier work on "la toile" in France is presented by Beauverie ('99) who calls attention to the fact that the fungus producing this disease has been considered by some to be *Botrytis cinerea,* and by others to be *Acrostalagmus albus,* a determination made in one instance at least by Oudemans ('92). This determination was based on material received from the Zoölogical Garden at Rotterdam. Beauverie obtained cultures but fails to describe how the fungus was isolated. From these cultures he was able to obtain only a sterile fungus, which, unfortunately, is not described. Failing to obtain spores he then proceeded with cultures originating from *Botrytis cinerea.* By growing this organism in a moist atmosphere at a temperature of about 33°C. a sterile form was induced. Again, by exposing cultures to a temperature somewhat lower, he affirms that he was able to develop a temporary sterile stage. It would appear that on the basis of these results he draws the conclusion that the first organism isolated represented also a sterile form of the *Botrytis.* He further emphasizes the point that the sterile form is the more dangerous in the production of disease, leading to the inference that conditions resulting in the development of this stage predetermined the prevalence of the malady. It is unsatisfactory to attempt to draw conclusions from this work, but it is at least probable that his first cultures may have been *Rhizoctonia,* and that, however accurately the work with *Botrytis* may have been carried out, it had really no connection with "la toile."

Lindau ('08) follows his discussion of *Rhizoctonia* with a paragraph dealing with the fungus producing disease in the cutting-bench and propagating-houses. The organism is described on the basis of the observations of Sorauer ('99) and Aderhold ('97), reference being made to the characteristic mycelium and chains of short cells, as well as to the occurrence of sclerotia. He questions the relationship with *Monilia,* sug-

gesting that the figures would indicate a closer relationship to *Hormiscium* or *Torula*. Since many of the American studies upon the potato and damping off fungus had previously been examined by him, as the account of *Rhizoctonia* indicates, it is surprising that the possibility of the identity of the "Vermehrungspilz" with *Rhizoctonia* was not suggested.

In his discussion of the fungus Ruhland ('08) considers the earlier work of Aderhold, Beauverie, and Sorauer. Special attention is given to that of Beauverie, and Ruhland takes the view that while in all probability the disease discussed by that investigator is the same as the disease of propagating-beds in Germany, Beauverie's cultures of *Botrytis* were not those of the disease-inducing organism. Ruhland studied the organism in culture, confirms the previous descriptions of mycelium, Monilia-like cells, structure of the sclerotia, etc. He would regard the sclerotia as sclerotial-like bodies (pseudosclerotia), owing to the fact that the structure is homogeneous throughout. Cultures of the fungus here discussed and of *Botrytis cinerea* were studied in parallel series with respect to the capacity to ferment cellulose, and it was found that while this capacity is possessed to a considerable degree by *Botrytis*, as had been previously established, the cellulose-dissolving capacity of the "Vermehrungspilz" is very low. He finds that in the development of the Monilia-like cells there is only a superficial resemblance to *Monilia*, since the spores of the latter are produced basipetally, while those of the seed-bed fungus are formed acropetally. The development of sclerotia from the Monilia-like masses is also noted. Apparently, he concluded that the old cells of the Monilia-like chains, as well as those of the sclerotia, were empty, hence incapable of germination. Earlier studies of *Rhizoctonia* have, however, shown clearly that many old cells of this type are capable of germination, and the peculiarities of this process have been figured and described (Duggar, '99).

In Java a disease of the Cinchona seed-beds was reported by Moens ('82). He describes the damping off of the seedlings as rapidly progressing radially, especially when the conditions are moist. The disease often begins at those points

where the drip from the defective roof falls on the seed-bed. The mycelium is described as spreading rapidly in the form of a web over the diseased plants and adjacent soil. Some observations were made by Stibbe ('06) who also reported that the disease may appear as early as during the first few days of growth. Koorders ('06) observed the disease in a young plantation. An examination of affected stems and roots was made, and a colorless, septate mycelium was found, but there were no evidences of fruiting stages. From these earlier observations of the Cinchona diseases in Java we have only the above evidences of the effect upon the host to suggest *Rhizoctonia* or a related fungus.

The investigations of Rant ('08, '14, '15, '15[a]), previously referred to, are sufficiently complete in all particulars to enable us to identify the fungus as *Rhizoctonia.* To this disease he applies the term "mopo" and "hamamopo" rather than the Dutch "Schimmeldraadjes." He found the effects upon the host to be as previously described, and noted particularly that the cobweb-like growth of the mycelium over the soil and dead plants occurred in a characteristic fashion when the area over the seed-bed was moist. He also emphasizes the point that fragments of soil are firmly held together by the growth of the fungous mycelium. Referring again to the distinctive characteristics of *Rhizoctonia* enumerated earlier, we find that his work covers every point there indicated. The fungus was found to affect not only Cinchona seedlings but was also found in his garden upon the following: *Lychnis diurna, Rudbeckia sp., Lobelia erinus, Conyza angustifolia, Bidens pilosa, Antirrhinum majus,* red beet, endive, cabbage, and lettuce. Culturing the fungus upon peptone glucose agar he obtained a good growth with all the characteristics of *Rhizoctonia* which have been referred to in my previous paper. Comparing his measurements with those previously reported, it is found that there is a close agreement throughout. The measurements also agree with those of Aderhold ('97). Rant also instituted a comparison between this fungus and *Botrytis cinerea,* and the results well emphasize the differences between these two organisms. He found likewise that the

"mopo" fungus bears no resemblance to *Acrostalagmus albus*, to which "la toile" in France had been occasionally referred. On the other hand, cultures of the "Vermehrungspilz" obtained from Amsterdam agreed closely with the organism isolated from Cinchona seedlings. Infection experiments with the "mopo" fungus were carried out both on Cinchona seedlings and on seedlings of the plants previously enumerated as affected. In all cases positive results were obtained.

Summary and Discussion.—From the reviews and discussion it seems justifiable to conclude that the common seedbed fungus in Germany and in France is identical with the damping off fungus which has been frequently studied in this country since the investigations of Atkinson ('92). I have given the evidence upon which the conclusion is based that the damping off fungus of the United States is Kühn's *Rhizoctonia Solani* (*Corticium vagum* B. & C.), the cause of important potato diseases and of other types of disease in a variety of host plants. The work of Rant enables us to include in this category of diseases due to *Rhizoctonia Solani* the disease of Cinchona seedlings and of other plants in Java. In establishing these points it is not necessary to consider the earlier and less complete reports upon "la toile" and the "Vermehrungspilz" but particularly the papers of Aderhold ('97), Sorauer ('99), Beauverie ('99), and Ruhland ('08).

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